

# Obtaining the Spin of the Proton from the Spins of the Quarks

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## ABSTRACT

*Employing the experimental electro-weak interactions between quarks and leptons, the spin of the proton may easily be understood in terms of the spins of the constituent quarks.*

Before considering how one may obtain the spin of the proton from the spin of the constitutive quarks, let us recall a simple fact about total spin zero momentum space wave functions for any two spin one half particles; e.g.

$$\Psi_{spin\ zero}(\mathbf{k}_1, \sigma_1, \mathbf{k}_2, \sigma_2) = \sqrt{\frac{1}{2}} \Phi(\mathbf{k}_1, \mathbf{k}_2) (\chi_{\uparrow}(\sigma_1)\chi_{\downarrow}(\sigma_2) - \chi_{\uparrow}(\sigma_2)\chi_{\downarrow}(\sigma_1)). \quad (1)$$

The probability distribution in momentum and spin for one of the particles, for example

$$P_1(\mathbf{k}_1, \sigma_1) = \sum_{\sigma_2} \int \frac{d^3\mathbf{k}_2}{(2\pi)^3} |\Psi(\mathbf{k}_1, \sigma_1, \mathbf{k}_2, \sigma_2)|^2, \quad (2)$$

does not at all depend on spin

$$P_1(\mathbf{k}_1, \uparrow) = P_1(\mathbf{k}_1, \downarrow) = \frac{1}{2} \int \frac{d^3\mathbf{k}_2}{(2\pi)^3} |\Phi(\mathbf{k}_1, \mathbf{k}_2)|^2. \quad (3)$$

Such an equipartition of spin probability would certainly *not* hold true for a total spin one polarized wave function; e.g.  $\Psi_{spin\ one}(\mathbf{k}_1, \sigma_1, \mathbf{k}_2, \sigma_2) = \Phi_{triplet}(\mathbf{k}_1, \mathbf{k}_2)\chi_{\uparrow}(\sigma_1)\chi_{\uparrow}(\sigma_2)$ .

Now, suppose that the proton is made up of three quarks ( $duu$ ), and further suppose the quarks are distributed as a spin zero diquark [1,2] and a spin one half quark. Say

$$(p) = (duu) = (du)_{(spinless\ diquark)} + u_{(quark)}$$

tied together by a “string” as in conventional fragmentation models. Under the above hypothesis, the momentum probabilities are independent of spin for the quarks in the diquark, *both*  $d \in (du)$  *and*  $u \in (du)$ , and only the isolated quark ( $u$ ) may have a momentum probability which depends on polarization. From lepton-proton scattering polarization measurements of spin,

$$s_{polarized} = \left(\frac{1}{2}\right) \eta, \quad (3)$$

only one third of the constituent quarks would theoretically exhibit the polarization in their momentum distributions,

$$\eta_{theory} = \left(\frac{1}{3}\right) \neq 1 . \quad (4)$$

The experimental number is[3-7]

$$\eta_{experiment} = 0.31 \pm 0.07 \quad (5)$$

in very reasonable agreement with the physical picture here presented.

## REFERENCES

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